AEI

Electrical Distribution

THE NEWS MAGAZINE OF THE CABLE AND CONSTRUCTION (CABLES & LINES) DIVISIONS OF ASSOCIATED ELECTRICAL INDUSTRIES LTD

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EDITORIAL

AMONG THE MANY common-sense suggestions made by Mr W. F. Jarvis (North Western Electricity Board) in his paper on *More Adequate Wiring* which he presented at Harrogate during the E.D.A.'s Annual Sales Conference, was that of making standard prices available for extra circuits with ring-main socket outlets, to be installed in dwellings where only one 15A socket is available. Some plan of this kind, together with other vigorous action by the electrical trade, is certainly necessary if the thousands of inadequately wired houses up and down the country are ever to possess, and use in safety, the many electrical labour-saving appliances available to their owners.

As Mr Jarvis rightly urged, "there is little time left to sow if we are to reap the rich harvest which could rightly be ours." For example, what happens when "topping-up" heat is required and the potential customer has no facilities for electric heaters? More likely than not, he thinks of the blanked-off gas socket which he has ignored for maybe twenty years and, remembering the Gas Board poster down the road which he has passed daily for months, off he goes and a sale is made—but not by an electrical stockist or contractor.

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OUR COVER PICTURE

Taken from the steps of the Tate Gallery, our picture shows the 34-storey tower of the Millbank development which is now under construction. Story on p. 79.

News in brief...

New Cable Service for the Midlands

A.E.I. CABLE DIVISION have established a new cable service for their customers in the Midlands who wish to obtain, without delay, low-tension paper-insulated mains cables from stock.

Facilities have been set up at A.E.I.'s Henley Foundries, Cradley Heath, Staffordshire, for the cutting, sealing, and dispatch of lengths to order. Stocks maintained at the Foundries initially comprise low-tension paper-insulated lead sheathed, served, single wire armoured and served cables, non-draining types to B.S. 480:1954.

This service is being administered by A.E.I. Birmingham District Office, 76–80 Sherlock Street, Birmingham 5. Telephone Midland 8391/2/3/4/5. Inquiries as to the sizes of cables available at any time will be welcome.

Useful E.D.A. Publication

A REVISED BOOKLET *Electricity Information Service* has been published by the Electrical Development Association. The booklet is a catalogue of the forms of information available from the Association on the uses of electricity in agriculture and horticulture. It lists booklets, technical books (Farm Electrification Handbook series), broadsheets, leaflets, 16mm films, 35mm filmstrips, and scale models which may be obtained or loaned from the E.D.A.

Copies of *Electricity Information Service* can be obtained from Electricity Boards' service centres and showrooms, or direct from the Electrical Development Association, 2 Savoy Hill, London, W.C.2.

Neon Sign Booklet

THE A.E.I. CABLE DIVISION has produced a revised version of its booklet *Behind the Signs* which gives particulars of neon sign cables and hints on their installation.

The booklet has been revised to take into account Amendment No. 2 to B.S. 599:1955, which relates to these cables. The amendment provides for smaller conductors, i.e. 19/·012in. in place of 37/·012in., and 1/·064in. in place of 1/·083in., as well as reduced thicknesses of insulation and sheath. The voltage ratings have also been altered. In addition, two screened and p.v.c. sheathed flexible types have been introduced, one being v.r. insulated and the other p.v.c. insulated: these have been added to the range of standard types in the booklet.

A copy of the new edition of *Behind the Signs* is available upon request to Associated Electrical Industries, Group Publicity Department, 155 Charing Cross Road, London, W.C.2.

Eastbourne–1961 B.E.P.C.

DELEGATES TO THE 1961 British Electrical Power Convention, which is being held at Eastbourne between 12–15 June, will hear four papers presented during the event. Presiding over the Convention will be the Chairman, Sir John Pickles, B.SC., M.I.E.E., who is Chairman of the South of Scotland Electricity Board.

The theme of the Convention will be "Electricity in the Prosperity and Welfare of the Nation". It is the thirteenth Convention to be held.

The full programme is as follows:

Monday, 12 June

3.00 p.m. **Opening of Convention.**
Civic Welcome.
Presidential Address.

Tuesday, 13 June

9.30 a.m. **Paper No. 1: "The British Electricity Transmission System"** by Sir Christopher Hinton, K.B.E., F.R.S., Chairman of the Central Electricity Generating Board.

2.45 p.m. **Paper No. 2: "Some Aspects of Efficiency and Economy in Distribution"** by Mr R. R. B. Brown, B.A., B.SC., Chairman of the Southern Electricity Board.

Wednesday, 14 June

9.30 a.m. **Paper No. 3: "The Electrical Power Industry in Canada"** by Dr A. E. Grauer, Chairman of the British Columbia Electric Company Limited, Vancouver, Canada.

2.45 p.m. **Paper No. 4: "British Electrical Manufacture in the National Economy"** by Mr S. F. Steward, C.B.E., M.I.PROD.E., Director of the British Electrical and Allied Manufacturers' Association.

Thursday, 15 June

10.00 a.m. **Electrical Forum.**
12 noon **Annual General Meeting.**

Cables for Braehead

THE SOUTH OF SCOTLAND ELECTRICITY BOARD has awarded to A.E.I. Construction (Cables and Lines) Division a £70 000 contract for the supply and installation at Braehead, Glasgow, of more than twelve miles of 11kV and lower-voltage paper and varnished cambric insulated cables, and more than fourteen miles of low-tension rubber-insulated, p.v.c. insulated and mineral-insulated copper clad cables.

These A.E.I. cables are intended for the additional 60MW set which will increase the generating capacity of the Braehead station from its present 200MW. All cabling is specified to be completed by the middle of this year.

HIGHEST IN ENGLAND

RESTING ON BORED piles sunk 90ft into London's blue clay, the thirty-four-storey tower of the new Millbank development will be England's highest reinforced-concrete structure.

The tower already dominates the skyline west of the Houses of Parliament as erection proceeds. When finished it will be 387ft high, the main part of a scheme to provide office and residential accommodation on a 3½-acre Thames-side site. Besides the tower there will also be an eight-storey Y-shaped block, 90ft high, and an eleven-storey residential block 120ft high, which will include eighty two-bedroom and one-bedroom flats, and a floor of ten hotel suites. Part of the 350 000sq.ft of office space will be used as the headquarters of the Vickers Group of Companies.

In the office part of the development, full air-conditioning will be provided, for which a space-saving medium high-velocity system has been adopted.

The development generally has been kept open at ground level as far as possible, space for occupation not commencing until the first floor. The architects, who are Messrs Ronald Ward and Partners, have taken advantage of this by planning an attractive layout of gardens and open courtyards.

The ground-floor level, however, will include a cinema/conference hall on the south side of the tower. Restaurants, messes, and kitchens for the various blocks will be on the first-floor podium.

There will be parking space for 250 cars on three levels, the cars proceeding to the parking spaces by means of a spiral ramp which cantilevers out from a water-storage tower.

Messrs Troughton and Young are electrical contractors for the project. A.E.I. cables are specified. Many miles of them will be installed throughout this lofty structure: cables ascending to the top of the high tower as rising mains, and cables for power, lighting, and internal communications laid in ducts above the suspended acoustic ceilings, to carry electricity for the many services which occupants will expect in this most modern of buildings.

The main contractors, Messrs Mowlem and Company, commenced work on the site in June 1959; construction is scheduled to be finished by the end of 1962. When that time arrives the building will take its place amongst London's proudest landmarks and will stand as an architectural achievement of the 'sixties.

An account of the cabling of the tower will, it is hoped, appear later in ELECTRICAL DISTRIBUTION as the building nears completion.

The Consulting Engineer is Mr G. W. Kirkland of Messrs R. Travers Morgan and Partners.

Network Calculations

by the load transfer and nodal voltage methods

by
A. SALZMANN, Dipl.Ing., A.M.I.E.E.

IN AN EARLIER paper published in *Distribution of Electricity*[1] the author described a method of network calculations less familiar to engineers. It was shown that by repeated transfer of loads to nodes and supply points, a network can be reduced to a single equivalent impedance.[2]

However, network reduction is not the only solution to this problem. Current flow in a complex network can be determined by the aid of nodal voltage and load transfer methods. We transfer the loads to nodes or supply points and solve the set of simultaneous linear algebraic equations by an iterative method, the latter being employed with success in high-speed digital computers.

As an illustration, let us consider the 3-phase network shown in Fig. 1. The circuits are fed via three supply points: *I*(C), *II*(G), *III*(F), and for clarity's sake we assume symmetrical loading and unity power factor load. It is required to determine the current distribution in each branch, assuming scalar impedances. This problem can be solved as follows:

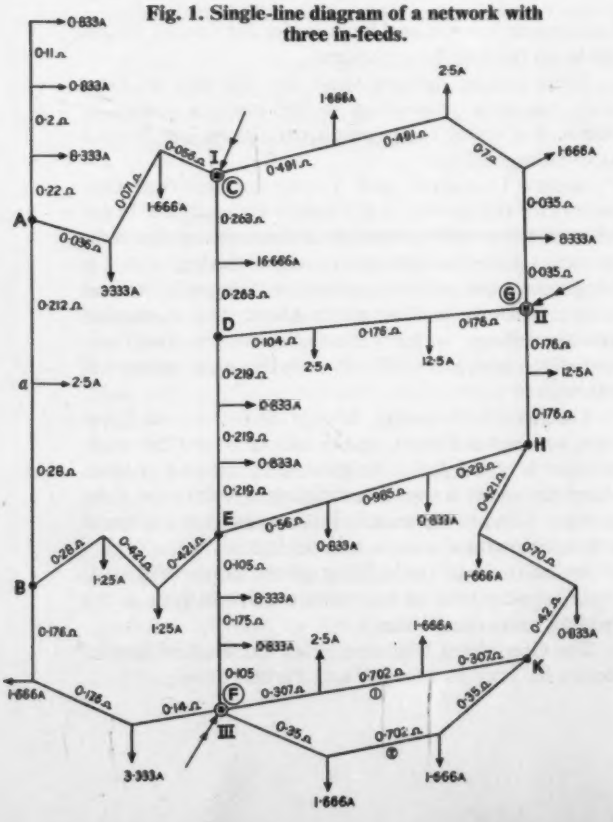

Fig. 1. Single-line diagram of a network with three in-feeds.

1. Load transfer

The first step is to transfer any tap-point current to the corresponding nodes. For example, current $I_a = 2{\cdot}5$A tapped off from branch AB is from nodes A and B. This current is divided into two components, namely $(I_a \times 0{\cdot}212)/(0{\cdot}212+0{\cdot}28) = 1{\cdot}0714$A placed at node B, and $(I_a \times 0{\cdot}28)/(0{\cdot}212+0{\cdot}28) = 1{\cdot}4286$A placed at node A, without altering the voltage distribution along the network. In a similar manner the rest of the tap-point currents are transferred to the appropriate nodes, as shown in Fig. 2 and Table 1. As a check, the sum of the currents transferred to nodes and supply points, namely $I_A+I_B+I_C+I_D+I_E+I_F+I_G+I_H+I_K = 105{\cdot}8332$A, must be equal to the total sum of currents demanded by the consumers ($\Sigma I = 105{\cdot}8332$A).

2. Setting up of nodal equations

The second step is the application of Kirchoff's law. The latter states that the sum of currents directed towards any node equals the sum of the currents directed

Table 1

Node	*Branch*	*Current Amp*	*Node*	*Branch*	*Current Amp*
A	Tail End	10·0	B	*BA*	1·0714
	AB	1·428		*BE*	1·4062
	AC	3·188		*BF*	2·0238
	I_A	14·617		I_B	4·5014
C	*CA*	1·8116	D	*DC*	8·3333
	CD	8·3333		*DE*	0·8333
	CG	4·5098		*DG*	6·7308
	I_C	14·6547		I_D	15·8975
E	*EB*	1·0938	F	*FB*	2·9762
	ED	0·8333		*FE*	3·2197
	EF	5·9469		FK_2	1·6667
	EH	0·7051		FK_1	2·3055
	I_E	8·5791		I_F	10·1681
G	*GC*	9·6568	H	*HE*	0·9615
	GD	8·2692		*HG*	6·2500
	GH	6·2500		*HK*	1·4394
	I_G	24·1761		I_H	8·6509
K	*KH*	1·0606			
	KF_2	1·6667			
	KF_1	1·8611			
	I_K	4·5884			

away from the nodes. Thus, say, for node E we have

$$I_{BE}+I_{DE}+I_{HE}+I_{IIIE}=I_E \quad \ldots\ldots\ldots\ldots(1a)$$

Since the current in each branch can be expressed as the product of branch admittance and potential difference between its ends, equation 1a rewritten becomes

$$V_{BE}Y_{BE}+V_{DE}Y_{DE}+V_{HE}Y_{HE}+V_{IIIE}Y_{IIIE}=I_E \quad \ldots(2a)$$

or

$$(V_B-V_E)Y_{BE}+(V_D-V_E)Y_{DE}+(V_H-V_E)Y_{HE} +(V_{III}-V_E)Y_{IIIE}=I_E \quad \ldots\ldots\ldots\ldots(3a)$$

However, in the nodal voltage method the potentials of the nodes are defined with reference to one node which is selected as the reference point. Thus for $V_I=V_{II}=V_{III}=V$ assuming equal and taking V as reference point and for $V-V_B=e_B$; $V-V_H=e_H$; $V-V_D=e_D$; and substituting in equation 3a, we get $[(V-e_B)-(V-e_H)]Y_{BE}+[(V-e_D)-(V-e_H)]Y_{DE}+[(V-e_B)-(V-e_H)]Y_{HE}+[(V)-(V-e_H)]Y_{IIIE}=I_E$... Re-arranging and substituting for $Y_{BE}+Y_{DE}+Y_{HE}+Y_{IIIE}=Y_{EE}$, we obtain the equation for node E

$$Y_{EE}e_E-Y_{DE}e_D-Y_{HE}e_H-Y_{BE}e_B=I_E \quad \ldots\ldots(4)$$

In this equation Y_{EE} represents the nodal self admittance and is equal to the sum of the admittances of all branches connected to node E. Y_{DE}, Y_{HE}, and Y_{BE} are nodal mutual admittances connecting two nodes directly. Notice that if two subscripts are alike, Y's are self admittances; if two subscripts are unlike we have mutual admittances.

In a similar manner we can determine the equations for the remainder of the nodes for the network, Fig. 1.

$$Y_{AA}e_A-Y_{BA}e_B=I_A \quad \ldots\ldots\ldots\ldots(1)$$

$$Y_{BB}e_B-Y_{AB}e_A-Y_{EB}e_E=I_B \quad \ldots\ldots\ldots\ldots(2)$$

$$Y_{DD}e_D-Y_{ED}e_E=I_D \quad \ldots\ldots\ldots\ldots(3)$$

$$Y_{EE}e_E-Y_{BE}e_B-Y_{DE}e_D-Y_{HE}e_H=I_E \quad \ldots\ldots(4)$$

$$Y_{HH}e_H-Y_{EH}e_E-Y_{KH}e_K=I_H \quad \ldots\ldots\ldots\ldots(5)$$

$$Y_{KK}e_K-Y_{HK}e_H=I_K \quad \ldots\ldots\ldots\ldots(6)$$

The numerical values of self and mutual admittances are given in Table 1.

3. Solution of nodal equations

The third step is to determine the nodal voltages. The foregoing equations are solved by the Gauss–Seidel[3] iterative method. Here we introduce a new unknown voltage e_o'. Substituting for currents and admittances the values given in Tables 1 and 2 and for $e_A=(e_A'-e_o')$; $e_B=(e_B'-e_o')$; $e_D=(e_D'-e_o')$; $e_E=(e_E'-e_o')$; $e_H=(e_H'-e_o')$ and $e_K=(e_K'-e_o')$ in the above n equation, adding the latter and changing signs of coefficients, we obtain progressively equations 1′ to 6′ as shown here, resulting in equation 7′.

A	B	D	E	H	K		
$+8{\cdot}235e_A'$	$-2{\cdot}035e_B'$	$+0$	$+0$	$+0$	$+0$	$-6{\cdot}2e_o'=+14{\cdot}617$	(1′)
$-2{\cdot}035e_A'$	$+4{\cdot}96e_B'$	$+0$	$-0{\cdot}89e_E'$	$+0$	$+0$	$-2{\cdot}035e_o'=+4{\cdot}5014$	....(2′)
0	$+0$	$+5{\cdot}613e_D'$	$-1{\cdot}52e_E'$	$+0$	$+0$	$-4{\cdot}093e_o'=+15{\cdot}8975$	....(3′)
0	$-0{\cdot}89e_B'$	$-1{\cdot}52e_D'$	$+5{\cdot}548e_E'$	$-0{\cdot}548e_H'$	$+0$	$-2{\cdot}59e_o'=+8{\cdot}5791$	....(4′)
0	$+0$	$+0$	$-0{\cdot}548e_E'$	$+4{\cdot}045e_H'$	$-0{\cdot}647e_K'$	$-2{\cdot}85e_o'=+8{\cdot}6509$	....(5′)
0	$+0$	$+0$	$+0$	$-0{\cdot}647e_H'$	$+2{\cdot}12e_K'$	$-1{\cdot}473e_o'=+4{\cdot}5884$	....(6′)
$+6{\cdot}2e_A'$	$-2{\cdot}035e_B'$	$-4{\cdot}093e_D'$	$-2{\cdot}59e_E'$	$-2{\cdot}85e_H'$	$-1{\cdot}473e_K'$	$+19{\cdot}241e_o'=-56{\cdot}8343$	....(7′)

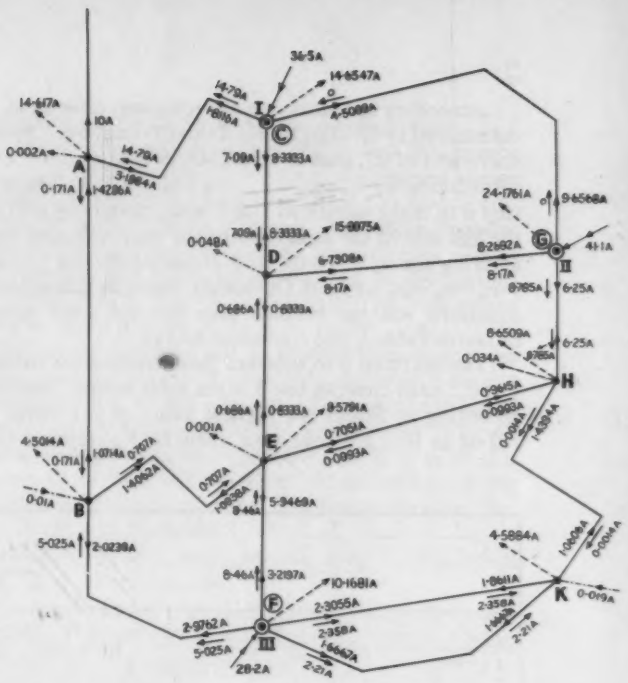

Fig. 2. Load and branch currents for the network shown in Fig. 1.

Table 2

Node	*Section*	*Mutual Admittance*	*Self Admittance*
A	*AI* $Y_{AI}=6{\cdot}2$ *AB* $Y_{AB}=2{\cdot}035$		$Y_{AA}=Y_{AI}+Y_{AB}=8{\cdot}235$
B	*BA* $Y_{BA}=2{\cdot}035$ *BE* $Y_{BE}=0{\cdot}89$ *BIII* $Y_{BIII}=2{\cdot}035$		$Y_{BB}=Y_{BA}+Y_{BE}+Y_{BIII}=4{\cdot}96$
D	*DI* $Y_{DI}=1{\cdot}90$ *DII* $Y_{DII}=2{\cdot}193$ *DE* $Y_{DE}=1{\cdot}52$		$Y_{DD}=Y_{DI}+Y_{DII}+Y_{DE}=5{\cdot}613$
E	*EB* $Y_{EB}=0{\cdot}89$ *ED* $Y_{ED}=1{\cdot}52$ *EH* $Y_{EH}=0{\cdot}548$ *EIII* $Y_{EIII}=2{\cdot}59$		$Y_{EE}=Y_{EB}+Y_{ED}+Y_{EH}+Y_{EIII}=5{\cdot}548$
H	*HE* $Y_{HE}=0{\cdot}548$ *HII* $Y_{HII}=2{\cdot}850$ *HK* $Y_{HK}=0{\cdot}647$		$Y_{HH}=Y_{HE}+Y_{HII}+Y_{HK}=4{\cdot}045$
K	*KIII*$_1$ $Y_{KIII_1}=0{\cdot}760$ *KH* $Y_{KH}=0{\cdot}640$ *KIII*$_2$ $Y_{KIII_2}=0{\cdot}713$		$Y_{KK}=Y_{KIII_1}+Y_{KH}+Y_{KIII_2}=2{\cdot}120$

According to Gauss, the approximate value of e_O' is determined by dividing the right side of equation 7′ by the coefficient of e_O', that is $-56{\cdot}8343/19{\cdot}241=-3{\cdot}0$V, and substituting for $e_A'=e_B'=e_D'=e_E'=e_H'=e_K'=0$. The next step is to make equations 1′ to 7′ zero, namely by shifting the left side of the equations to the right side and substituting for $e_O'=-3{\cdot}0$V and provisionally for $e_A'=e_B'=e_D'=e_E'=e_H'=e_K'=0$. Obviously, the right side of these equations will not become zero but will have values shown in Table 3, line 2, columns 8 to 14.

The next step is to subtract the currents given in lines 1 and 2, thus creating line 3 in the table below. Selecting according to Seidel the highest value of I/Y from $I_D'=3{\cdot}62$ in line 3 in our case, then I_D'/Y_{DD} representing $e_D'=3{\cdot}62/5{\cdot}613=0{\cdot}6$ volts—an approximate value of the nodal voltage (see Table 3/4/4). Substituting again in equations 1′ to 7′ for $e_D'=0{\cdot}6$V and for $e_A'=e_B'=e_D'=e_E'=e_H'=e_K'=0$, we obtain a new set of currents for entering in line 4. In this manner we proceed until the nodal voltage approaches the value zero—in our case $e_D'=0{\cdot}001$V: Table 3, line 44.

Thus the Gauss–Seidel iterative process as performed by digital computer develops a new set of currents at each iteration. This process is said to converge if successive iterations produce currents differing from previous values and the nodal voltages approach zero values.

As a check: the sum of the currents in any line of the table below must be about zero. For example, in line 30

Table 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
	COLUMN NUMBERS														
								I_O'	I_A	I_B	I_D	I_E	I_H	I_K	*Remarks*
1	e_O'	e_A'	e_B'	e_D'	e_E'	e_H'	e_K'	−56·83	14·61	4·50	15·89	8·57	8·65	4·58	
2	−3·0							−57·72	−18·60	−6·11	−12·28	−7·77	−8·55	−4·42	
3								+0·89	−3·98	−1·61	+3·62	+0·81	+0·10	+0·17	$+\frac{3{\cdot}62}{5{\cdot}613}=+0{\cdot}6$
4				+0·6				+2·46	0	0	−3·37	+0·91	0	0	
5								+3·35	−3·98	−1·61	+0·25	+1·72	+0·10	+0·17	$-\frac{3{\cdot}98}{8{\cdot}235}=-0{\cdot}5$
6		−0·5						−3·10	+4·12	−1·017	0	0	0	0	
7								+0·25	+0·17	−2·627	+0·25	+1·72	+0·10	+0·17	$-\frac{2{\cdot}627}{4{\cdot}96}=-0{\cdot}5$
8			−0·5					−1·017	−1·017	+2·48	0	−0·445	0	0	
9								−0·767	−0·877	−0·147	+0·25	+1·275	+0·10	+0·17	$+\frac{1{\cdot}275}{5{\cdot}548}=+0{\cdot}2$
10					+0·2			+0·518	0	+0·178	+0·304	−1·11	+0·11	0	
11								−0·249	−0·877	+0·031	+0·554	+0·165	+0·210	+0·17	$-\frac{0{\cdot}877}{8{\cdot}235}=-0{\cdot}1$
12		−0·1						−0·620	+0·823	−0·204	0	0	0	0	
13								−0·869	−0·054	−0·173	+0·554	+0·165	+0·210	+0·17	$+\frac{0{\cdot}554}{5{\cdot}613}=+0{\cdot}1$
14				+0·1				+0·409	0	0	−0·561	+0·152	0	0	
15								−0·416	−0·054	−0·173	−0·007	+0·317	+0·210	+0·17	$+\frac{0{\cdot}17}{2{\cdot}12}=+0{\cdot}08$
16							+0·08	+0·118	0	0	0	0	+0·052	−0·17	
17								−0·342	−0·054	−0·173	−0·007	+0·317	+0·262	0	$+\frac{0{\cdot}262}{4{\cdot}045}=+0{\cdot}06$
18						+0·06		+0·171	0	0	0	+0·033	−0·243	+0·039	
19								−0·171	−0·054	−0·173	−0·007	+0·350	+0·019	+0·039	$+\frac{0{\cdot}350}{5{\cdot}548}=+0{\cdot}06$
20					+0·06			+0·154	0	+0·053	+0·091	−0·333	+0·033	0	
21								−0·017	−0·054	−0·120	+0·084	+0·017	+0·052	+0·039	$-\frac{0{\cdot}120}{4{\cdot}96}=-0{\cdot}02$
22			−0·02					−0·041	−0·041	+0·099	0	−0·018	0	0	
23								−0·058	−0·095	−0·021	+0·084	−0·001	+0·052	+0·039	$+\frac{0{\cdot}039}{2{\cdot}12}=+0{\cdot}02$
24							+0·02	+0·029	0	0	0	0	+0·013	−0·042	
25								−0·029	−0·095	−0·021	−0·084	−0·001	+0·065	−0·003	$+\frac{0{\cdot}065}{4{\cdot}045}=+0{\cdot}02$
26						+0·02		+0·057	0	0	0	+0·011	−0·081	+0·013	
27								+0·028	−0·095	−0·021	+0·084	+0·010	−0·016	+0·010	$+\frac{0{\cdot}084}{5{\cdot}613}=+0{\cdot}01$
28				+0·01				+0·041	0	0	−0·056	+0·015	0	0	
29								+0·069	−0·095	−0·021	+0·028	+0·025	−0·016	+0·010	$-\frac{0{\cdot}095}{8{\cdot}235}=-0{\cdot}01$
30		−0·01						−0·062	+0·082	−0·020	0	0	0	0	
31								+0·007	−0·013	−0·041	+0·028	+0·025	+0·016	+0·010	$-\frac{0{\cdot}041}{4{\cdot}96}=-0{\cdot}01$
32			−0·01					−0·020	−0·020	+0·050	0	−0·009	0	0	
33								−0·013	−0·033	+0·009	+0·028	+0·016	−0·016	+0·010	$+\frac{0{\cdot}028}{5{\cdot}613}=+0{\cdot}005$
34				+0·005				+0·020	0	0	−0·028	+0·008	0	0	
35								+0·007	−0·033	+0·009	0	+0·024	−0·016	+0·010	$+\frac{0{\cdot}010}{2{\cdot}12}=+0{\cdot}005$
36							+0·005	+0·007	0	0	0	0	+0·003	−0·011	
37								+0·014	−0·033	+0·009	0	+0·024	−0·013	−0·001	$+\frac{0{\cdot}024}{5{\cdot}548}=+0{\cdot}004$
38					+0·004			+0·011	0	+0·003	+0·006	−0·022	+0·002	0	
39								+0·025	−0·033	+0·012	+0·006	+0·002	−0·011	−0·001	$-\frac{0{\cdot}033}{8{\cdot}235}=-0{\cdot}004$
40		−0·004						−0·025	+0·033	−0·008	0	0	0	0	
41								0	0	+0·004	+0·006	+0·002	−0·011	−0·001	$-\frac{0{\cdot}011}{4{\cdot}045}=-0{\cdot}0033$
42						−0·0033		−0·008	0	0	0	−0·002	+0·012	−0·002	
43								−0·008	0	+0·004	+0·006	0	+0·001	−0·003	$+\frac{0{\cdot}006}{5{\cdot}613}=+0{\cdot}001$
44				+0·001						0					
	−3.0	−0·614	−0·530	+0·716	+0·264	+0·083	+0·105	Check: Sum of currents in each line must approach zero							

we have $-0{\cdot}062+0{\cdot}082-0{\cdot}02=0$. The actual nodal voltages are determined by adding the voltage value in each column from 1 to 7. Thus we obtain:

$e_O'=-3{\cdot}0\text{V}$; $e_A'=-0{\cdot}614\text{V}$; $e_B'=-0{\cdot}530\text{V}$; $e_D'=0{\cdot}716\text{V}$; $e_E'=0{\cdot}264\text{V}$; $e_H'=0{\cdot}083\text{V}$; $e_K'=+0{\cdot}105\text{V}$ and $e_A=e_A'-e_O'=2{\cdot}386\text{V}$; $e_B=e_B'-e_O'=2{\cdot}47\text{V}$; $e_D=e_D'-e_O'=3{\cdot}716\text{V}$; $e_E=e_E'-e_O'=3{\cdot}264\text{V}$; $e_H=e_H'-e_O'=3{\cdot}083\text{V}$; $e_K=e_K'-e_O'=3{\cdot}105\text{V}$.

4. Branch currents

The fourth step is to calculate the branch currents. Knowing the nodal voltages, we determine the current in each branch as the product of branch admittance and the potential difference between its ends. For, say, branch AB, we have $I_{AB}=(V_A-V_B)Y_{AB}=[V-e_A-(V-e_B)]Y_{AB}=(e_B-e_A)Y_{AB}=(2{\cdot}47-2{\cdot}386)2{\cdot}035=0{\cdot}171\text{A}$. Similarly,

$I_{IIIB}=2{\cdot}7\times2{\cdot}035=5{\cdot}025\text{A}$
$I_{BE}=(3{\cdot}105-3{\cdot}083)0{\cdot}647=0{\cdot}0014\text{A}$
$I_{IIH}=3{\cdot}083\times2{\cdot}85=8{\cdot}785\text{A}$
$I_{IA}=2{\cdot}386\times6{\cdot}2=14{\cdot}79\text{A}$
$I_{ED}=(3{\cdot}716-3{\cdot}264)1{\cdot}52=0{\cdot}686\text{A}$
$I_{BE}=(3{\cdot}264-2{\cdot}470)0{\cdot}89=0{\cdot}707\text{A}$
$I_{IID}=3{\cdot}716\times2{\cdot}193=8{\cdot}17\text{A}$
$I_{IIIK_2}=3{\cdot}105\times0{\cdot}713=2{\cdot}21\text{A}$
$I_{IIIK_1}=3{\cdot}105\times0{\cdot}760=2{\cdot}358\text{A}$
$I_{II_1}=0$
$I_{ID}=3{\cdot}716\times1{\cdot}9=7{\cdot}09\text{A}$
$I_{IIIE}=3{\cdot}264\times2{\cdot}59=8{\cdot}46\text{A}$
$I_{BE}=(3{\cdot}264-3{\cdot}083)0{\cdot}548=0{\cdot}0993\text{A}$

To check: According to Kirchoff's law, the sum of the load and branch currents at any node must be zero. However, owing to slide-rule calculations, small errors are inevitable (see Fig. 2).

Node A: $I_{IA}=I_A+I_{AB}=14{\cdot}617+0{\cdot}171=14{\cdot}788\text{A}$; $I_{IA}=14{\cdot}79\text{A}$
Error represents a fictive demand of $14{\cdot}79-14{\cdot}788=0{\cdot}002\text{A}\simeq0{\cdot}02\text{A}$

Node B: $I_{AB}+I_{IIIB}=I_B+I_{BE}$; $0{\cdot}171+5{\cdot}025=5{\cdot}196\text{A}$; $4{\cdot}5014+0{\cdot}707=5{\cdot}208\text{A}$
Error represents a fictive supply of $5{\cdot}208-5{\cdot}196=0{\cdot}012\text{A}\simeq0{\cdot}01\text{A}$

Node D: $I_D=I_{ID}+I_{ED}+I_{IID}=7{\cdot}09+0{\cdot}686+8{\cdot}17=15{\cdot}946\text{A}$; $I_D=15{\cdot}8975\text{A}$
Error represents a fictive demand of $15{\cdot}946-15{\cdot}8975=0{\cdot}0485\text{A}$

Node E: $I_{BE}+I_{HE}+I_{IIIE}=I_E+I_{ED}$; $0{\cdot}707+0{\cdot}0993+8{\cdot}46=9{\cdot}2663\text{A}$; $8{\cdot}579+0{\cdot}686=9{\cdot}265\text{A}$
Error represents a fictive demand of $9{\cdot}2663-9{\cdot}265\simeq0{\cdot}001\text{A}$

Node H: $I_{IIH}=I_H+I_{HE}+I_{HK}$; $I_{IIH}=8{\cdot}6509+0{\cdot}0993+0{\cdot}0014=8{\cdot}7516\text{A}$
Error represents a fictive demand of $8{\cdot}785-8{\cdot}7516=0{\cdot}034\text{A}$

Node K: $I_{IIIK_1}+I_{IIIK_2}+I_{HK}=I_K$; $I_K=2{\cdot}358+2{\cdot}21+0{\cdot}0014=4{\cdot}5694\text{A}$
Error represents a fictive supply of $4{\cdot}5884-4{\cdot}5694=0{\cdot}019\text{A}$

5. Current distribution and maximum voltage drop

The final step is to determine the current flow in each branch of the network. The current distribution shown in Fig. 3 is obtained by superimposing the branch currents on the load currents. As an illustration, consider branch AB. Load current $I_a=2{\cdot}5\text{A}$ transferred to node A and flowing from A to a is $1{\cdot}4286\text{A}$ (Fig. 2). Branch current flowing from A to B is equal to $0{\cdot}171\text{A}$, hence total current flowing from A to a is $1{\cdot}4286+0{\cdot}171\simeq1{\cdot}6\text{A}$ (Fig. 3). Load current $I_a=2{\cdot}5\text{A}$ transferred to node B and flowing from B to a is $1{\cdot}0714\text{A}$ (Fig. 2). Branch current flowing from A to B is equal to $0{\cdot}171\text{A}$, hence the total current from B to a is $1{\cdot}0714-0{\cdot}171\simeq0{\cdot}9\text{A}$ (Fig. 3). The current flowing from nodes A and B to point a is therefore $1{\cdot}6+0{\cdot}9$ and will meet the demand $I_a=2{\cdot}5\text{A}$. In a similar manner, we determine the current distribution of the total network.

Check: Voltage drop around loop L (encircled, Fig. 3) must be about zero.

$8{\cdot}001\times0{\cdot}14+4{\cdot}668\times0{\cdot}176+3{\cdot}001\times0{\cdot}176+2{\cdot}113\times0{\cdot}28+0{\cdot}863\times0{\cdot}421-0{\cdot}387\times0{\cdot}421-2{\cdot}513\times0{\cdot}105-10{\cdot}847\times0{\cdot}175-11{\cdot}68\times1{\cdot}05=0{\cdot}109\simeq0{\cdot}10\text{V}$.

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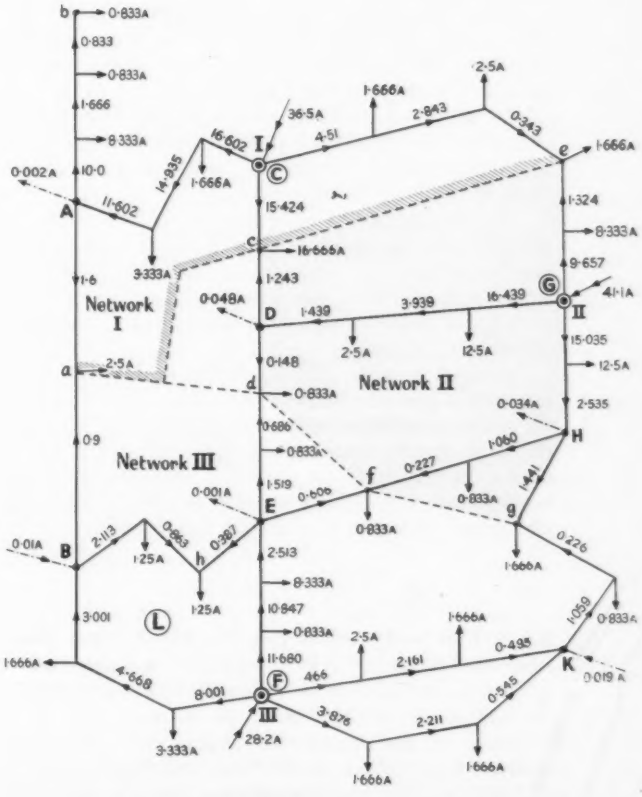

Fig. 3. Current distribution of the network shown in Fig. 1.

Maximum voltage drop.

Point a: $\Delta E = e_A + 0{\cdot}212 \times 1{\cdot}6 = 2{\cdot}734$V
Point b: $\Delta E = e_A + 10 \times 0{\cdot}22 + 0{\cdot}8333 \times 0{\cdot}2 + 8{\cdot}333 \times 0{\cdot}11 = 4{\cdot}697$V
Point c: $\Delta E = 15{\cdot}424 \times 0{\cdot}263 = 4{\cdot}07$V
Point d: $\Delta E = e_D + 0{\cdot}148 \times 0{\cdot}219 = 3{\cdot}716 + 0{\cdot}325 = 4{\cdot}04$V
Point e: $\Delta E = 4{\cdot}51 \times 0{\cdot}491 + 2{\cdot}843 \times 0{\cdot}491 + 0{\cdot}343 \times 0{\cdot}7 = 3{\cdot}85$V
Point f: $\Delta E = e_E + 0{\cdot}606 \times 0{\cdot}56 = 3{\cdot}264 + 0{\cdot}34 = 3{\cdot}604$V
Point g: $\Delta E = e_N + 1{\cdot}441 \times 0{\cdot}421 = 3{\cdot}083 + 0{\cdot}605 = 3{\cdot}688$V
Point h: $\Delta E = e_E + 0{\cdot}387 \times 0{\cdot}421 = 3{\cdot}42$V

Summary

The solution of network calculation problems by the aid of the load transfer and nodal voltage method offers advantages when dealing with complex circuits. This method is straightforward compared with the reduction method outlined in a previous article.[1] The solution of a relatively small number of linear equations by slide rule, paper, and pencil and applying the Gauss–Seidel iterative method is possible within reasonable time. However, the use of a digital computer is inevitable for a circuit in which solution by the nodal voltage method involves a very large number of equations and greater accuracy is required.

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1. SALZMANN, A. Distribution Network Calculations. The Load Transfer Method of Solution. *Distribution of Electricity*, March 1960, pp. 396 *et seq.*
2. MCPHERSON, J. B. Load Flow Calculations. *Electrical Review*, 23 December 1949, pp. 1191 *et seq.*
3. RZIHA & SEIDENER. *Starkstromtechnik. Book.* Wilhelm Verlag, Berlin, pp. 632 *et seq.*

New British Standards

B.S. 3288:1960—Insulator and Conductor Fittings for Overhead Power Lines. Part 1—Performance and General Requirements

A new Standard, setting out performances for the various kinds of fittings used in close association with the insulators and conductors on overhead power lines. It gives general requirements and specifies tests.

A second part, now in course of preparation, will be concerned with dimensional standardization and will be confined to a limited range of fittings, based on present practice in the United Kingdom.

The mechanical requirements of the Standard are related to the failing load of the fitting. It is left to the user to decide on the relationship between the maximum working load and the specified minimum failing load, with due regard to all the circumstances and any relevant statutory regulations.

Some of the tests, particularly the heating-cycle test for tension and non-tension joints and anchor clamps, are not yet established in commercial practice. For this reason it may be necessary to review the specification after a shorter interval than would normally elapse before revision, with a view to making any amendment that may appear desirable in the light of experience.

Price 5*s.* 0*d.*

B.S. 137:1960—Porcelain and Toughened Glass Insulators for Overhead Power Lines (3·3kV and upwards)

This is a revision of the 1941 edition. It incorporates the addendum of 1946, in which insulator pins were standardized, and extends the range of standard string insulator units up to a specified minimum failing load of 42 000lb. The test requirements are closely in line with those of Publications 75 and 87 of the International Electrotechnical Commission, which deal respectively with porcelain and glass insulators.

The designs of ball-and-socket couplings have been revised and are now the same as those recommended in I.E.C. Publication 120. This change, while maintaining interchangeability with existing British designs, ensures complete interchangeability with string insulator units made in any of the principal manufacturing countries.

Price 15*s.* 0*d.*

B.S. 3297:1960—High-voltage Post Insulators

A new standard for porcelain and toughened glass insulators for 3·3kV and upwards (the same voltage range as that covered by B.S. 137). The insulators specified are designed to give rigid support to busbars, isolators, and air-break switch parts in substations, and for similar applications. Mechanical and electrical tests are included to ensure that the insulators are suitable for these duties. The specification is closely in line with B.S. 137, B.S. 223, "High voltage bushings", and the draft recommendations of the I.E.C. on post insulators. Detailed information about post insulator units in common use in Great Britain is given in an appendix.

Price 10*s.* 0*d.*

B.S. 162:1961—Electrical Power Switchgear and Associated Apparatus

This new edition of B.S. 162 replaces the 1938 edition. It brings up to date the requirements for electrical power switchgear and associated apparatus for use at voltages greater than 100V for d.c. and for a.c. at power frequencies. *Price* 17*s.* 6*d.*

Price of B.S. 162C (*set of drawings*) 30*s.* 0*d.*

Copies of these standards may be obtained from the B.S.I., Sales Branch, 2 Park Street, London, W.1.

The Cross-Channel Cable Sea Trials

W. G. HAWLEY, A.M.C.T., A.M.I.E.E., Chief Engineer, Cable Division,
and W. SIM, Chief Engineer, Construction (Cables and Lines) Division

THE CROSS-CHANNEL d.c. power cables* are due to be laid in midsummer, and it is pertinent to recall the experimental laying trials which were held in October 1958, to determine the feasibility of the proposals for laying and repairing the cables.

The trials were conducted jointly by the two contracting companies, A.E.I. and B.I.C.C., on behalf of the Central Electricity Generating Board.

The Laying Vessel

The question of availability of a custom-built cable-laying ship and the modification which it would require to fit it for laying the large and relatively heavy power cable rather than the lighter telephone and telegraph cables for which it is normally equipped, led to the choice of the C.E.G.B. collier, *Dame Caroline Haslett*. This ship, although requiring modifications for the laying, satisfied the important requirement of being small enough to work inshore to simplify the laying of the shore ends of the cables.

The *Dame Caroline Haslett* is a motor vessel of 2 700 tons with two holds of sufficient capacity to accommodate all the cable required for the main laying, and possessing a third hold in which to store other equipment, such as buoys, moorings, other auxiliary tackle, and h-v testing gear. The vessel has a length of about 230ft and a beam of 40ft.

The ship is equipped with echo-sounding apparatus, Decca Navigator and radar. To adapt her as a cable-laying ship special gear had to be installed and the principal items were:

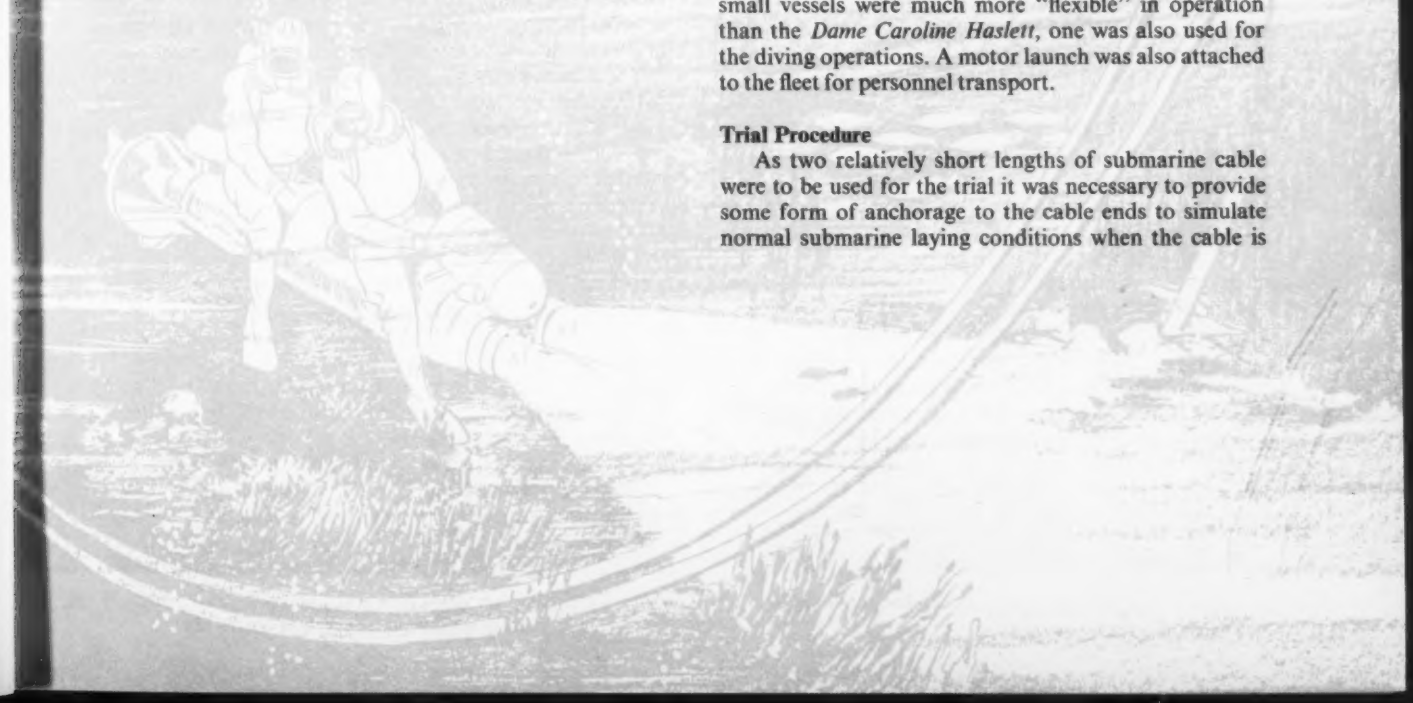
1. Transporter gear for coiling the long lengths of cable from the drums into the holds;
2. Fairleads to allow the cable to run freely without friction between the holds and the stern skid;
3. Compression brakes: (*a*) hydraulic, and (*b*) hand operated. Although the hand-operated brakes were installed for standby purposes they will actually be used in the final operation;
4. Stern skid to control the bending radius of the cable when leaving the ship to enter the water;
5. Hauling-in gear (or cable machine) for hauling in the cable ends from the seabed for the jointing operations;
6. An "A" frame fitted on the bows to support the joints when being carried across the deck to be lowered into the sea;
7. A bow skid which acts in the same way as the stern skid and controls the bending radius when the cables are being paid out or brought in for jointing operations.

The *Dame Caroline Haslett* left Woolwich prior to the trials and proceeded to Calais. There she picked up a French diving team with their diving equipment and a special miniature submarine which was to be used for underwater examination and photography; she then returned to Dover for final preparations.

At Dover the laying vessel was joined by two motor-driven fishing boats, which were to be in attendance for the trials in order to render any assistance required for maintaining course, as well as to help control the *Dame Caroline Haslett* during the repair operations. As these small vessels were much more "flexible" in operation than the *Dame Caroline Haslett*, one was also used for the diving operations. A motor launch was also attached to the fleet for personnel transport.

Trial Procedure

As two relatively short lengths of submarine cable were to be used for the trial it was necessary to provide some form of anchorage to the cable ends to simulate normal submarine laying conditions when the cable is



* The cables are now being manufactured by A.E.I. and B.I.C.C., the joint contractors for the British part of the project. Details of the scheme appeared in the July 1960 issue of ELECTRICAL DISTRIBUTION.

anchored ashore, and it was decided to do this by means of mooring anchors attached by adequate lengths of mooring chain and wire rope to the leading ends of the cables in the ship's holds. The chains and ropes were first of all led along the fairleads and then through the compression brakes; the anchors were attached and paid over the stern skid; and when the anchorage was such as to enable the cable ends to be pulled from the holds of the vessel, the ship was set on her course. A similar procedure, but in reverse, was also adopted on the trailing ends of the cable; that is, wire rope, chain, and mooring anchors all laid in line, thus assuring that when the cables had to be lifted for the trial repair, the conditions then obtaining were similar to those to be expected in the repair of long lengths of submarine cable.

In a job of this nature difficulties are bound to arise, and the first attempt to lay the mooring anchors was not entirely successful. After some days of intervening bad weather, a second attempt was made: this time anchor, mooring chain, and cable were all successfully laid out.

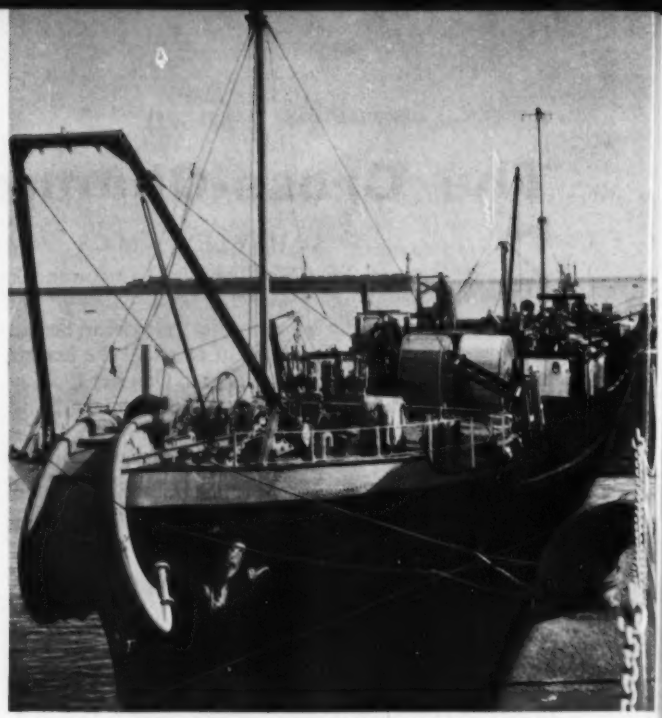
To maintain the requisite spacing of the cables, laying tension and laying speed have, of course, to be closely controlled so that the two cables take up the same angle of lead from the stern skid.

The hydraulic compression brakes, referred to earlier, took control of the speed and tension of cables for a time; but after a short period the brakes failed to respond fully to their release mechanism and recourse had to be made to the hand-operated brakes for the remainder of the lay. The operators skilfully manipulated the hand brakes and had no difficulty in maintaining the speeds and tensions necessary to ensure that the cables were paid out correctly.

Following the laying, the divers examined and took photographs of the cables on the channel floor, and they found that the two cables were to all intents and purposes dead straight, with a separation between them not exceeding one metre. "Still" photographs were obtained by skin divers; and another diver, sitting astride a miniature electrically driven submarine, filmed the cable run at the time of making an inspection.

The next stage of the tests, involving cable repairs, was held up by recurring bad weather, during which time changes in the tides made diving operations difficult. Consequently, it was decided to proceed on a revised schedule which called for a closing joint to be made on the lengths of cable on drums aboard the *Dame Caroline Haslett*. This entailed the layout of moorings for the ship at the remote ends of the cable, the paying out of the closing joint and, at the same time, the recovery of the two ends of the laid cable on which to make the repair joints, i.e. one in each cable. This would be followed by the relay of the repair joints, the recovery of the moorings, and finally the application of a high-voltage d.c. test to the installation. A demonstration of grappling and the underwater cutting of cables would follow.

All preparations were in hand for simulating the repair operation and a 500-ton cargo vessel, the m.v. *Stork*, was chartered to carry the four mooring anchors



▲ **The *Dame Caroline Haslett* at Dover with drums aboard. The bow skid and "A" frame are seen in close-up.**

which the *Dame Caroline Haslett* would require. These moorings were successfully laid out with the assistance of one fishing vessel which was used to transfer the mooring lines from the *Dame Caroline Haslett* to the *Stork*.

The divers then went down and attached a heaving line to the remote ends of both the laid cables which were hauled in over the bow skid, the cables being fleeted-in by attaching a messenger rope and passing this rope on to the drum of the hauling-in gear. About 110yd of the cable on the drums were eased out and approximately 70yd recovered from the laid cables. The cables were now secured over the bow skid by means of wire-rope stoppers run over rubber buffers (to prevent damage to the cables), and the jointing operations were started.

The jointing was carried out by two skilled jointers and two mates to each joint, and it was completed in under sixteen hours.

A joint was used identical with submarine repair joints of the type used by the A.E.I. Woolwich works for some years, the protective outer casing being a somewhat cumbersome metal shell about 10ft long with substantial armour clamps to take the tension on the two cable ends prior to jointing, the shell being in two halves bolted around the actual cable joint.

The joints had to be manœuvred from the deck towards the bows of the ship and the "A" frame, and in order to maintain the close spacing of the cables the joints, and the cables some few feet either side of them, had to be lashed together; and as the joints had, for convenience, been made athwartships, the handling of them was rather a tricky operation.

At the time the joints were being manœuvred towards the bows the laying vessel had to be warped sternwards to allow the joints to be lowered overboard, and at the

same time care had to be taken to ensure that the joints were not lowered on to the cables already on the seabed.

When the joints and the jointed-in sections of cable had been lowered they were again inspected by divers and photographed.

The vessel then proceeded to the landward end of the two laid cables where the two ends recovered were brought aboard for testing, the testing equipment being set up ready for use in one of the holds. The complete installation was given a high-voltage d.c. test of 200kV negative polarity for thirty minutes, and passed the test satisfactorily. It was not possible to complete the test with an equivalent positive potential, as unfavourable tidal conditions made it necessary to return the cable ends to the seabed rather hurriedly.

The next operation on the programme was one of demonstrating the severing of cables underwater by means of explosives, and for this the *Dame Caroline Haslett* proceeded to Dungeness East Roads, where a mooring was laid out followed by the laying of two lengths of cable from the spare cable left on the drum. The cables were brought above water to have explosive charges attached to each of them, and the latter were then wired up to a detonating switch on deck. The cables and charges were returned to the seabed in a depth of approximately eight fathoms. The charges were detonated and the severed ends recovered; in each case the cable was found to be completely severed at the charge position, and the appearance of the severed ends was surprisingly tidy.

There again followed some days of inclement weather before it was possible to start the recovery operation on the original installation. It had originally been intended to cut all the lashings on the joints and cables so that the recovery could begin at one end of the cable and continue right through, recovering cable and joints as a single unit. But the divers found that sand had covered the cables near the joints and all the lashings could not be cut. After a protracted all-night operation, the complete assembly was hauled aboard in rather an inelegant fashion.

The rather unwieldy type of joint suffered a little damage on being hauled over the bow sheath.

The *Dame Caroline Haslett* then returned to Woolwich where the cables and joints were unloaded for examination and test.

Lessons Learnt

It was clearly shown that the two cables can be laid simultaneously to lie close to each other on the seabed. The exception to this is in the vicinity of a repair where spacing could not be guaranteed because of the method and the heavy type of joints used. Subsequent work with a flexible type of joint has proved, however, that a satisfactory repair can be made without undue difficulty.

The use of a converted collier for the trial proved satisfactory, and some modification to the cabling equipment will make the *Dame Caroline Haslett* quite suitable for the laying of a long submarine cable.

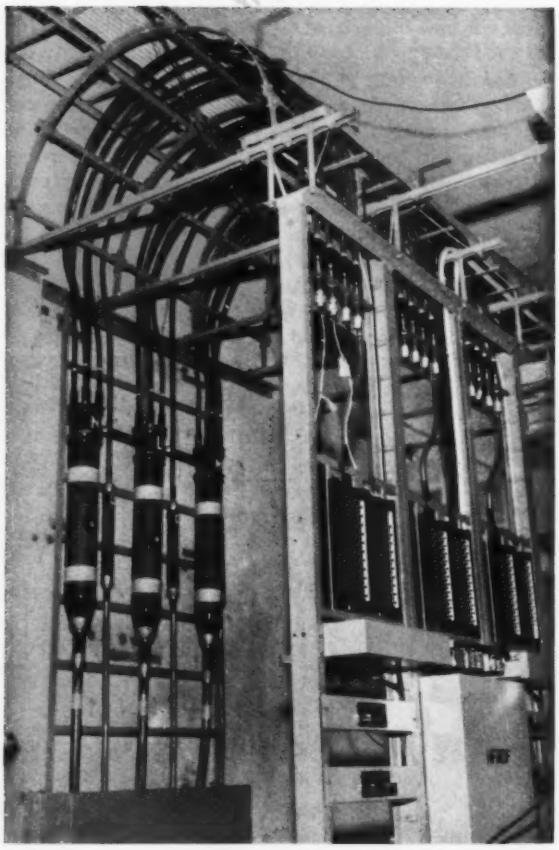
Since weather and tidal conditions can change quickly, time is a most important consideration in the making of joints at sea, and the more quickly they can be carried out, by simplifying design and by special training of jointers, the less likelihood there is of operations being adversely affected by the possibility of sudden deterioration in weather conditions.

The experience gained did clearly indicate the need for a lighter and more flexible type of joint, and in fact this will be put into effect when the final cables are laid.

▲ Cable-laying in progress during the trials. The two cables run evenly over the stern, side by side.

▲ One of the French frogmen going over the side to examine the joints made during the trials.

Cable-laying for Nigeria's Telecommunications



The carrier room at the new automatic exchange, Ibadan, showing terminations of three 4-coaxial pair cables with three 14-pair 40lb carrier cables.

Since 1955, A.E.I. engineers have been laying telephone cables in Nigeria for the biggest telecommunications modernization programme in West Africa.

NIGERIA is more than three times the size of Britain. The seat of government is Lagos and the country, which celebrated its independence last year, consists of three regions: the eastern, whose regional capital is Enugu; the western, with Ibadan as its regional capital; and the northern, regional capital Kaduna.

This article is concerned chiefly with the improvement of the Ibadan network and its associated exchanges at Ife, Ilesha, Oshogbo, and Ilorin, which are shown on the accompanying map. A few words on the overall picture of Nigerian telecommunications as planned by the Nigerian Posts and Telegraphs Department will, however, serve to place the A.E.I. work in Nigeria in perspective.

The main triangle between the regional capitals has been served by a VHF radio link since 1956, the date of its completion by A.E.I. engineers in collaboration with the Nigerian authorities. This main network also included certain intermediate stations between the capitals and was extended to serve other towns around Enugu and Kaduna. Today certain parts of the VHF system have been replaced with equipment working at a higher frequency—ultra high frequency or UHF—to provide television, telegraph, and speech channels. The Lagos to Ibadan link, the first VHF link to be established in

NIGERIA'S TELEPHONES
Map showing the telephone exchanges mentioned in this article.

Nigeria, was also the first to be converted to UHF, a changeover which was completed at the beginning of 1960.

There are 40 000 telephones in Nigeria. The Nigerian Posts and Telegraphs Department's present programme plans to provide twelve new major automatic telephone exchanges, to enable local subscribers to call each other without the assistance of an operator. The result will be dial service for 70% of Nigerian telephone subscribers.

Associated Electrical Industries is playing a large part in the installation or supply of equipment for eight of these exchanges: Ibadan, Enugu, and Kaduna (the three regional capital exchanges), Oshogbo, Ilorin, Ife, and Ilesha (previously mentioned) and Onitsha in the eastern region. The first two were cut into service last year; all will be in operation by the end of 1961. The three A.E.I. divisions collaborating in the installations are the Telecommunications Division, the Cable Division, and the Construction (Cables and Lines) Division.

The Ibadan System

The new Ibadan automatic exchange was installed by the General Electric Company, and A.E.I. engineers installed the cable network. Initially it serves 1 400 subscribers and will be able to serve 3 000 lines as demand increases. The other four stations, which lie within a range of seventy miles of Ibadan, are smaller. Oshogbo has an initial capacity of 280 with a final capacity of 1 000 lines, Ilorin will at first be able to cater for 300 subscribers but can be extended to serve 1 000, and the exchanges at Ife and Ilesha each have 280 lines capacity and are capable of expansion to 1 000 lines.

Telephone exchanges and their distribution systems use large quantities of cables. For Ibadan, 142 miles of A.E.I. cables were installed, containing 31 000 miles of wire. This included fifty-six miles of paper-insulated lead covered cable laid in concrete troughing, thirty-eight miles of armoured cable laid direct in the ground, and thirty-seven miles of polythene insulated underground cable. About 2½ miles of lead covered cable were installed, lashed to catenary wire supported by poles, and nearly eight miles of polythene cable were also installed overhead.

Cables have been installed to the specification of the Nigerian Posts and Telegraphs Department. Several different methods were used.

The concrete troughing, specially designed by the Posts and Telegraphs Department, is of **U** section capped with a concrete cover. The concrete is heavily reinforced to British Road Transport specification. The overhead

suspension system was used in certain parts of the native quarter of Ibadan, where the pathways are ill defined and are, moreover, subject to changes in location which may make future access to the cables difficult. Special co-axial cables were protected by asbestos cement or pitch fibre ducts.

The Nigerian Posts and Telegraphs Department produce their own poles from Nigerian opepe timber and have built a timber-impregnating plant at Ibadan for pressure treating these poles. A total of 711 poles was erected for the Ibadan scheme.

There were 1 057 joints made on the Ibadan cables and the huge number of 18 645 core pairs made off at exchanges or cabinets—at an average rate of 455 pairs a day. A.E.I. jointers at first carried out all the jointing, but as they gradually trained local men the latter eventually took over this work. A laying rate for cables of 420yd a day was established. On the job were ten European and 120 local staff, and four sub-contractors employing 500–600 local men engaged in trenching and cable-laying.

Chief cause for concern was the propensity for termites to attack polythene laid direct in the ground—a problem to which no satisfactory solution has yet been found by the Nigerian authorities.

For the schemes at Ife, Ilesha, and Oshogbo more than thirty-two miles of distribution cables have been laid or erected, involving the making of approximately 270 joints and 118 block terminations. At Ilorin, where work is still going on, nearly fourteen miles of cable, 180 joints, and 125 plug joints are involved.

Besides equipping these new exchanges, A.E.I. Cable Division has supplied 1 100 miles of cable during the past five years for smaller telephone distribution networks and the stock supplies which must be maintained in the country.

One of the most interesting phases of this varied work was the crossing of the river Benin near Sapele in 1959, as part of a scheme to improve trunk connections between Sapele and Lagos. At Lagos a motor barge loaded two drums which each held 1 800ft of telephone cable, and proceeded for five days' steaming to traverse the inland creeks to Sapele, where the drums were off-loaded to enable the cable to be re-coiled in the hold of the vessel. The next task was to hack at a 300yd-long belt of semi-floating marine vegetation which lay just off-shore and roll it back like a carpet before the cables could be laid. The trenches on either side of the river presented a further problem, as the "ground" turned out to consist of packed, rotting timber and axes had to be used literally to hack out the excavations!

Other lengths of submarine cable were laid across the river Niger, the third longest river in Africa. In 1957 two 3 500ft lengths of telephone cable were laid on the bed of the Niger to connect the exchanges at Asaba and Onitsha. The cable was coiled in the hold of a local boat at Lagos which proceeded up-river under its own steam to the laying location where the cable was laid through brake gear rigged in the stern.

There were many problems to cope with and overcome in Nigeria, not the least being the ever-present possibility of stepping on a poisonous snake. But perhaps the most flabbergasting incident, and a good one to close this story on, was the overhead section which was slung over a native building still in the course of erection. When the building was finished a horrified engineer spotted the lines—going in one window and out of another!

The crossing of the river Benin near Sapele.

(Above)
Conditions were far from ideal.

Coiling the cable in the barge at Sapele.

E.A.F. Equipment

Portable equipment for the safe drying of faulty insulation

OF INVALUABLE use in ships, where the ingress of moisture is a major source of trouble, and with wide applications in other situations, a self-contained portable apparatus for the *in situ* detection of faulty insulation and the removal of moisture is now available from the Marine Department of A.E.I. Telecommunications Division.

Known as E.A.F. Equipment, its compact dimensions are 15¾in. by 15¾ in. by 21½in. It has already proved itself in many marine applications, including the drying-out of the entire electrical installation of a floating dock which had been completely submerged, and it will be readily acknowledged as a serviceable piece of equipment in the routine maintenance of ships' electrical plant.

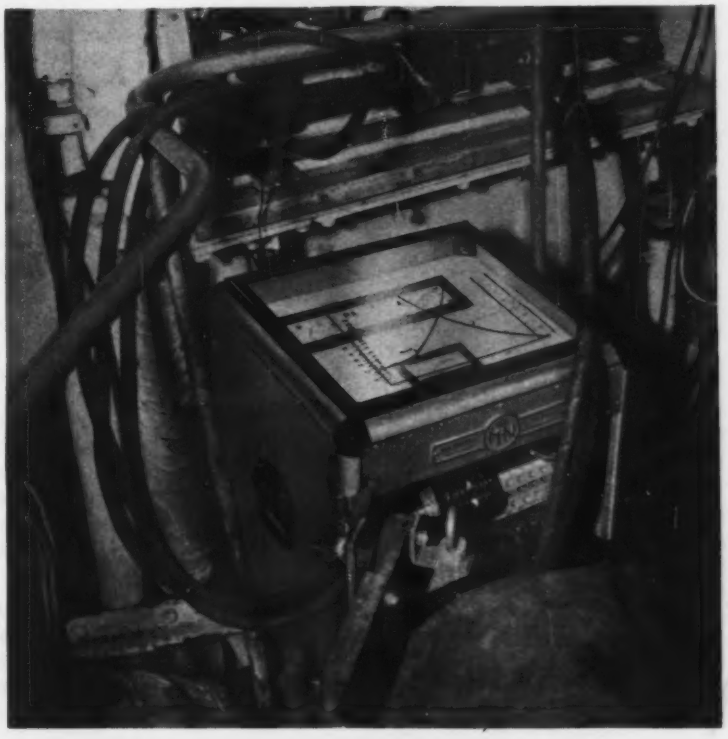
The E.A.F. Equipment operates from 220V 50–60 cycles a.c. Ships with direct current require a converter unit suitable for the equipment in order to use it at sea.

It is essentially a low-potential source of supply of drying current which is passed through the circuit whose insulation is found to be faulty. Possible damage to plant owing to overheating is avoided by a thermostat which controls the drying temperature, and a resistance thermometer is provided as a further check that this does not happen. The unit is also fitted with a voltmeter and an ammeter to indicate voltage and current during the drying-out process, and a megohmmeter for the monitoring of the insulation resistance. The front of the unit swings down for access to the operating panel mounting the controls. Above the operating panel are "cable-size" terminals for connecting 3/·036in., 7/·029in., 7/·036in., 7/·044in., and 7/·052in. cables. Voltage terminals on the back of the equipment are nominally marked 2V, 5V, 10V, 15V, 20V, 25V, 30V, and 60V. Maximum output of 2kVA is available.

On the top plate of the unit a graph shows the relationship between the load, heating effect, and the life of cables under various drying conditions. The curves apply only to long-term overloading of cables, as short-term loading is not a serious matter. A table is also printed on the top plate, giving the correct drying current for a particular size of cable and also relating the latter to its correct "cable size terminal".

Drying out a Cable

To dry out moisture from a cable, the remote end is first short-circuited. If the cable contains more than two cores it may be enough to use only two for drying purposes. A multicore cable may be effectively dried by short-circuiting all the conductors at the remote end,



E.A.F. Equipment being used to dry out an electrical installation on a cruiser. ▶

separating the conductors into two groups at the other end, and connecting to the equipment as a two-core cable. From the table of values, the correct drying current is chosen and the appropriate voltage required to supply that current is found by experiment on the output terminals. By pressing a test button marked "0" during the drying period, the drying current is switched off and the insulation resistance of the cable is shown on the megohmmeter. Thus the resistance is revealed while the cable is warm and any latent insulation faults are more readily detected. As the temperature of the cable rises, the moisture moves towards the ends of the cable; here its concentration rises rapidly, but because the supply voltage is low there is no flashover. Drying out is accomplished in very little time, however, and by finishing the ends of the cable with insulating varnish and tape, further penetration of moisture may be avoided to a large extent.

When a larger size cable has to be dried out than is allowed for by the marked "cable-size" terminals, these terminals are ignored and the terminal marked "0" is used for switching in. Thermostatic control does not operate in this case and the ammeter and voltmeter are used as checks. No damage to the cable through overheating will result using E.A.F. Equipment, and the equipment itself is protected from overloading by automatic fuses.

Testing and Drying Out Motors

Testing and drying out of motors is carried out by testing through the motor feeder or by switching directly into the terminal board of the motor. The rise in temperature of the motor is mainly due to iron losses and the drying current need not, therefore, be particularly high. By heating the motor from the core, the moisture moves out, and experience has shown that any salt content in the water will, for the most part, gather on the surface of the motor winding and can easily be removed by compressed air after the moisture has been eliminated.

Perhaps the most valuable role played by the E.A.F. Equipment is a preventive one. A ship's electrician can work out his own routine for testing the electrical installation. From the ship's main board he will be able to test all outgoing cables to distribution boards and motors. He can then choose whether to move the equipment to individual distribution boards and continue testing, or to complete his routine checking from the main board.

E.A.F. Equipment, marketed by A.E.I. Marine Department of Woolwich, London, S.E.18, is made in Norway by Marinens Hovedverft, Horten. A.E.I. Marine Department has sole marketing rights all over the world with the exception of Norway, Sweden, Denmark, Finland, France, Holland, Germany, and the Soviet Union.

Wiring Regulations*

Interpretations

THE THIRTEENTH EDITION of the Regulations for the electrical equipment of buildings was issued on 1 September 1955, and amendments were approved by the Council of The Institution having effect from 15 December 1958. The following abstracts of interpretations, the ninth group to be published,† are of general interest and involve clear-cut issues.

Inquiry 61 *Regulations* **108, 111, 203, 204(A)**

Regulation 109 of the twelfth edition stated that every distribution fuseboard shall be connected to either (i) the main switchgear; (ii) a separate way on a larger distribution fuseboard; or (iii) one or more other distribution fuseboards by looping into their busbars.

Regulation 109 has been omitted from the thirteenth edition. Are both (ii) and (iii) above still in compliance with the Regulations, or is only (ii) (or the equivalent of a separate fuse in the loop connection) now admissible?

Reply

The essence of Regulation 109 of the twelfth edition is embodied in the basic requirements of the thirteenth edition, as to the choice and protection of cables. Attention is called in particular to Regulations 108, 111, 203, and 204(A).

It is confirmed that a distribution fuseboard may be connected by any of the three methods described in Regulation 109 of the twelfth edition, provided that all the requirements set out in the thirteenth edition are observed.

In particular it will be necessary, for compliance with Regulation 108, to ensure that, if a distribution board is connected by looping into the busbars of another distribution board, the cables used are adequately protected by the sub-main fuse or circuit-breaker from which the supply is obtained, i.e. the current rating of the looping cables is not less than that of the cables used to feed the other distribution board. If, because of length of run and voltage drop, some parts of the looping cables were made of larger size than others, the protection must be appropriate to the smallest cable used.

In addition, it must be ensured that the method of looping cables into the distribution fuseboards is such that their busbars do not get hotter than is prescribed in British Standard 214 (see Regulations 302(A) and 601), and that the cable terminations are mechanically and electrically sound in accordance with Regulation 207.

Inquiry 62 *Regulation* **314(B)**

The reply to inquiry 58 appears to indicate that for each floor-warming circuit an isolating switch additional to any automatic-control device is necessary for compliance with the Regulations.

* Reprinted from the *Journal of The Institution of Electrical Engineers*, Volume 7 (New Series), February 1961.

† Reprints of the earlier sets of abstracts remain available, price 6d. each post free. Details of these may be obtained from the Secretary of The Institution.

The Note to Regulation 314(B)(ii), however, states "For the purpose of this clause the term 'appliance' includes a heating installation which may consist of several parts." This seems to make it quite clear that a number of floor-warming circuits can be connected to a distribution board and controlled by one isolating switch. Confirmation of this would be appreciated.

Reply

Regulation 314(B) must be read with Regulations 7 and 116(A), and it will be for the designer of each installation to determine the placing of isolating switches so as to provide an "effective means suitably placed for easy operation" for cutting off the supply to every part of the system.

In some installations it may be possible, depending on the layout and method of use of the premises, to comply with the above Regulations by the use of a single isolating switch for a number of floor-heating final subcircuits. It will, however, be necessary to consider whether such a switch can be so placed that it is available at all times for ready operation by those having charge of the premises or any part thereof, particularly in an emergency.

Inquiry 63 *Regulations* **401, 402(D)**

Regulation 402(D) requires that one point of the secondary winding of any transformer used in a consumer's installation shall be earthed; but this, it must be noted, is only as a means of compliance with Regulation 401. Regulation 401 is specifically restricted to apparatus operating at above extra-low voltage. Transformer secondaries operating at extra-low voltage are therefore apparently exempt from earthing. Is this correct?

Reply

No. A transformer having a winding or windings operating at a voltage exceeding extra-low voltage must be regarded in its entirety as coming within the scope of Regulation 401, and the metalwork (other than current-carrying parts) of the transformer and one point of the secondary winding (including an extra-low-voltage secondary winding) must be earthed in accordance with Regulation 402(D), except where one of the Exemptions to that Regulation applies.

It may be noted that, with particular exceptions (see p. 2 of the Introduction), wiring and equipment operated at voltages not exceeding 15 volts between lines or to earth are not required to satisfy the provisions of the Regulations; such installations must, however, be segregated from those operating at higher voltages, and any isolating transformer used must be installed in accordance with the requirements of the Regulations.

Inquiry 64 *Regulation* **405**

May a heated carpet underlay situated within a room containing a fixed bath be installed to comply with the requirements of the Regulations? It would appear that such an installation should comply with the requirements of Regulation 405, but there are two problems.

First, since no provision shall be made for the use of portable appliances, in what way may the heated underlay be connected to the supply? Secondly, serious consequences may arise from possible shock to a person stepping out of a bath full of water, even assuming that a bath mat is used having, in dry conditions, adequate insulating properties. The steamy atmosphere of a bathroom would give rise to condensation and may result in the bath mat, the carpet and the underlay retaining some moisture content and thus presenting some leakage path to earth, through a human body and the bath.

Reply

An electrically heated carpet underlay falls within the terms of the definition of "appliance" set out on p. 7 of the Regulations. For the purposes of this reply, it is assumed that the inquiry relates to an underlay operated directly at mains voltage.

Regulation 405(C) states that no provision shall be made for the use of portable appliances in a room containing a fixed bath. The connection of an appliance of the type in question by means of a plug and socket-outlet is therefore clearly precluded by the Regulations.

It has been ruled in the past that the term "fixed appliance" denotes an appliance which cannot be removed without the use of tools; and an electrically heated carpet underlay, unless permanently fixed to the floor, cannot be regarded as complying with this definition; it must thus be regarded as a portable appliance, and its use in a room containing a fixed bath would contravene Regulation 405(C).

If such an underlay were permanently fixed to the floor and connected to the supply by means of fixed wiring, Regulation 405(C) would be complied with. It would then be necessary to ensure that the construction and installation of the underlay complied with the requirements of Regulations 304 and 305 for apparatus in damp situations, and of Regulation 614 in the absence of a particular British Standard.

It is thought that many of the types of carpet underlay at present available would not comply with these last-named Regulations, and failure so to comply could clearly give rise to serious danger in a bathroom. The requirements of Regulations 314(B)(iii) and 405(B) as to the placing of the means of control must also be observed.

Inquiry 65 *Regulation* **710**

A number of small box-type signs, each containing a small transformer, are to be hung on the external walls of buildings, approximately 10ft above pavement level.

Does Regulation 710 require a "danger, high voltage" notice to be fixed to these displays, in view of the fact that all the h-v equipment is contained within the sign itself and is therefore not "accessible to an unauthorized person" unless the sign is dismantled?

Reply

The phrase in Regulation 710 "accessible to unauthorized persons" relates to containers or enclosures

Continued at foot of next page

Book Reviews

The Dielectric Circuit *By* **Philip Kemp**
Chapman and Hall
219 *pp.* *Price* 45*s.* 0*d.*

This book gives a more comprehensive treatment of dielectric theory than is to be found in normal textbooks designed to cover a general course in electrical technology.

The first chapter is concerned with the necessary definitions applicable to electrostatic theory. Chapter two deals with capacitance in various conductor arrangements and chapter three continues this line of investigation by examining the behaviour of capacitors on alternating voltage, bringing in long transmission lines and associated effects. A treatment of capacitance in 3-phase overhead and cable systems follows.

Chapter five introduces a discussion on potential gradient which is extended in the next chapter by its application to cylindrical conductors (cables) with reference to different cable types. The concluding chapters cover transients in various capacitive circuits and the effects of impulse voltages. The final chapter describes methods of dielectric measurement in high-voltage testing.

The book should prove extremely useful to the serious student of high-voltage engineering, to whom a good knowledge of dielectric phenomena is becoming increasingly important.

Michael Faraday *By* **Alan E. Jeffreys**
Chapman and Hall
86 *pp.* *Price* 42*s.* 0*d.*

Full title of this volume is *Michael Faraday: a list of his lectures and public writings*. It is a carefully collated and fascinating list of the written work signed by or attributed to Faraday, arranged in chronological order. From the first lecture in 1816 to the City Philosophical Society: *On the general properties of matter* to the last item from Faraday's pen included in a Parliamentary paper concerning the electric light in 1866, the year before his death, the books, letters, papers, and lectures illustrate Faraday's amazing breadth of interest in scientific subjects.

Wiring Regulations *continued*

for ancillary equipment for h-v discharge-lighting installations and not to the ancillary equipment itself.

In the circumstances described in the inquiry, where ancillary h-v equipment is contained within a discharge-lamp fitting, the need or otherwise for a "danger, high voltage" notice must be determined by the designer of the installation, who must judge whether or not the fitting is "accessible to unauthorized persons". Height above ground does not alone necessarily render a fitting inaccessible; and the designer should consider, for example, whether the fitting may be reached from a window, and the need for cleaning of the fitting.

Basic Ultrasonics *By* **Cyrus Glickstein**
Chapman and Hall
137 *pp.* *Price* 32*s.* 0*d.*

An American publication describing clearly in a non-technical manner, with the aid of numerous drawings and diagrams, the general theory, equipment, and applications of modern ultrasonic progress. An interesting book for student and layman.

P.V.C. Insulated Cables
Effect of new British Standard

A.E.I. ARE NOW producing cables to B.S. 2004:1961, *P.V.C. Insulated Cables and Flexible Cords*.

This edition provides for 250V types to have thinner insulation and, in most cases, thinner sheath than catered for in the previous issue (1953). It also introduces twin, 3-core and 4-core screened flexible cords for use in what are termed "flameproof situations", as well as 660V cables, which also have insulation and sheath thicknesses less than those previously regarded as standard.

A feature of the new Specification is the change in voltage designation. Cables and flexible cords corresponding to the former 250V types are now designated 250/440V, whilst cables corresponding to the previous 660V types are designated 660/1 100V.

A.E.I. Erecting Pole Lines for Rural Electrification

THE YORKSHIRE ELECTRICITY BOARD has awarded a contract to the A.E.I. Construction (Cables and Lines) Division for the supply and erection of five miles of 33kV wood pole line, together with the re-arrangement of existing lines, in the Wold Newton district.

Construction is single- and double-circuit to Y.E.B. specifications, using 0·175sq.in. steel-cored aluminium conductors on porcelain insulators. Completion date is June 1961.

A.E.I. Construction Division is at present engaged in rural wood pole schemes in North Wales and Buckinghamshire.

For the C.E.G.B. Northern Project Group they have commenced construction on five miles of 33kV single-circuit unearthed lines of H-pole construction at Cwm Rheidol in connection with the hydro scheme on the river Rheidol some miles from Aberystwyth. The conductors are of 0·15sq.in. steel-cored aluminium and an aerial pilot cable is also supported on the poles. Consulting Engineers are Messrs Kennedy and Donkin.

Between Chesham and Great Missenden, Buckinghamshire, A.E.I. construction crews are erecting two 33kV single-circuit wood pole lines for the Eastern Electricity Board. Each line is 5¾ miles in length, of unearthed construction, using 0·2sq.in. stranded aluminium conductors.

Total value of these three A.E.I. contracts is £73 000.

E D A Annual Conference
28 February — 3 March
Sales attitudes emphasized

AFTER THE OPENING address by Mr David Irving, B.SC., M.I.E.E., chairman of the E.D.A. Council, Mr J. I. Bernard, M.I.E.E., addressed delegates at Harrogate on the activities of the Electrical Development Association, of which he is a director.

Five papers were presented during the conference.

Mr C. Nield, A.M.I.E.E., A.M.B.I.M., of the Midlands Electricity Board, presented a paper on *Presentation of Merchandise in Service Centres*. After emphasizing that increased domestic appliance sales were one factor in maintaining stable prices for electricity, he went on to show how, by attention to attractive window display, and by linking displays to appliance manufacturers' own advertising themes, the Service Centre should aim at establishing itself as the "best shop in town" for advice on and the purchase of electrical appliances.

Display requirements and the desirability of on-the-spot demonstrations require facilities which should be recognized in the design stage of the interior layout of Service Centres. Mr Nield described methods of producing display material, and concluded with details of the training given to assistants in the Midlands Board area.

Mr S. F. Steward, C.B.E. (director, B.E.A.M.A.), showed early in his paper on *The Future of Domestic Appliances* that the increasing use of electrical appliances in today's homes, and present socio-economic trends, indicated expanding markets. With an increase in the use of electricity went the primary consideration of safety, and this had resulted in the formation of the British Electrical Approvals Board for Domestic Appliances.

The criterion of "one per household" was becoming an obsolete sales term for many product groups. Another point to be considered was the ever-increasing range of new appliances.

Mr Steward reviewed the chief electrical appliance product groups, outlining new technical advancements being developed within each, and the psychological problems to be overcome in many cases in order to increase sales. He also examined Government policy and the separate responsibilities of the manufacturers and the Electricity Boards, concluding that there is a strong case for co-operation in promoting electrical development.

About half of the paper *More Adequate Wiring* by W. F. Jarvis, ASSOC.I.E.E., A.M.B.I.M. (North Western Electricity Board) reviewed past wiring standards or, rather, the lack of their application until the sudden surge of post-war interest headed by the publication, in 1944, of the I.E.E. Committee report: "Post War Building Studies No. 11—Electrical Installations". Between 1945–7 the Consumers' Service Unit, the ring main, and 13A plugs and sockets became standardized.

Mr Jarvis then passed to considerations of future domestic loads, which are growing heavy enough to warrant some forethought and preparation. He suggested that a need would arise for a standard distribution or kitchen control unit incorporating a timer: final sub-circuit fuses with certain pre-selected circuits individually switched. With a 30A timer it would be possible to have simultaneous operation of any number of appliances up to a total loading of 7·2kW.

He mentioned the "Gold Medallion Home" scheme promoted by the Duke Power Company, North Carolina, to encourage load-building. These homes have full electrical facilities for every aspect of home comfort. In this country he would like to see similar "drive" in tackling the problem of bringing existing, old installations up to date. There was need for co-operation between contractors and Boards on standard pricing for improvements to existing circuits, in order to encourage consumers, and long-term easy-payment facilities should be available.

In his paper on *The Control of Off-peak Floor Warming in Domestic Premises*, Mr A. F. Hardcastle, M.I.E.E. (Southern Electricity Board), expressed the hope that "the time when one is chilled on moving from a warm room to an unheated room will shortly be a thing of the past." He surveyed briefly the methods available at present for the control of off-peak supplies: by individual time switches; by time switches and contactor in multi-storey buildings; and centralized remote systems of control by d.c. bias system, rhythmatic system, and pilot wire in distribution mains.

He discussed the various factors which must be taken into account when considering these methods, and then passed to the question of who should control the extent of the floor warming—landlord or tenant. Factors such as the proper use of the installation, responsibility for cost, and fairness to tenants enter into the question. Costs and consumptions for existing installations were discussed and given in tabulated form.

Mr A. Ellison, A.M.I.E.E. (North Eastern Electricity Board), opened his paper on *The Board and the Small Industrial Consumer* with the provocative statement: "It would appear that Area Boards have not directed the same attention to the small industrial consumer as they have to the domestic, commercial, and rural consumer." He defined the small industrial consumer as one having a demand less than 100kW.

After giving interesting breakdown figures for demand, revenue, etc., of such consumers in the Tees Sub-Area of the N.E.E.B., he went on to define the various aspects of service which they should receive from the Board. Consumers' power requirements should be related to suitable tariffs brought into line with costs.

Suitable staff should be trained to look after the interests of the small industrial consumer, and Mr Ellison gave a summary of the duties of the technical sales and service engineer, especially with regard to field work. He concluded his paper with a brief survey of the scope for development of the use of electricity in light industry.

PROBLEM CIRCLE

A VERY NICE postbag indeed resulted from home readers' efforts at the resumed Problem Circle posers set in the January issue. Solutions from overseas readers have not, of course, reached us yet (at the time of writing) but we are expecting a fair response.

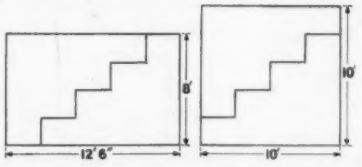
If anything was needed to emphasize the popularity of this feature, it was provided by the letters received from stalwarts of the Circle whose names are familiar to us from past correspondence. It was hailed with the delight reserved for meeting old friends. As Mr R. Lawson put it: "*Gaudet tentamine virtus!*" Bows all round.

Another encouraging aspect of this first postbag was the very large number of new entrants—to these a hearty welcome is extended, with the hope that perseverance will bring its own reward. Most of those who stay with us do it for the enjoyment of solving the problems, but the prize is always there to egg one on.

One or two new problems were received, and we hope to write to their senders soon.

January Problems

Problem No. 1 was solved correctly by about one-third of the entrants. The remaining answers apparently worked on the truism that a straight line is the shortest distance between two points! But we asked for the minimum number of pieces, not the minimum number of cuts. The diagram shows the rather neat solution to this problem. Each "step" is 2ft deep by 2ft 6in. wide.



The winner of the £1 10s. for this problem is **Mr J. R. Roff, 306 Oakwood Lane, Leeds 8, Yorks.**

Problem No. 2 attracted many more replies than the first one. Nobody found a solution better than the one comprising 17 moves which we possessed, and this is the problem for which **Mr R. Lawson, 56 Chandag Road, Keynsham, nr Bristol,** gets the prize. The 17 moves are neatly presented in his solution: for the benefit of those who failed to solve this problem correctly, we give it here.

Containers		*Contents*																
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*
16	16	7	7	7	7	5	5	5	5	3	3	3	3	1	1	1	8	0
9	0	9	2	0	7	9	2	0	7	9	2	0	7	9	2	0	0	0
7	0	0	7	7	0	0	7	7	0	0	7	7	0	0	7	7	0	0
'A'	0	0	0	2	2	2	2	4	4	4	4	6	6	6	6	8	8	8
'B'	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8

Mr C. F. Wells, of Rugby, separated the first 8 measures in 14 moves without once tipping any into the customers' pails, by a nice bit of sleight of hand. But actually supplying the customers took care of the remaining three moves left to him.

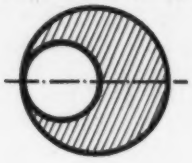
Mr R. C. H. Connolly, our old friend from Watford, solved No. 2 although he slipped up on No. 1. But he gave an alternative "solution" to the milkmaid problem in such a delightful piece of verbal slapstick that it would be reproduced if we had room. Suffice to say that it involved knocking off the handle of the 7-measure jug, filling it with muck, and sinking it in the 9-measure jug. Lo, we have a 2-measure container, and the rest is easy, compensating for the thickness of the smaller jug by a system of drip-drainage into different customers' pails on alternate days!

March Problems

The first of our March problems involves a geometrical construction. The second requires a little juggling with letters as substitutes for numbers: each horizontal line spells a word.

Problem No. 3

Given two circles as shown, the smaller one being half the radius of the other, find a construction to divide the shaded portion into three equal parts.



Problem No. 4

This is in the popular form of a word sum:

2
49
411
9 461
72 407
149 940
7 546 725
69 674 725
457 856 760
699 257 410
1234 567 890

Solutions to Problem Circle

Solutions to the Problems 3 and 4 should be sent to the Editor, ELECTRICAL DISTRIBUTION, 155 Charing Cross Road, London, W.C.2. Envelopes should be marked "Problem Circle". *Closing Dates:* 20 April 1961 for competitors resident in Great Britain, Northern Ireland, and Eire. For overseas competitors the *mailing date* specified is 12 May.